

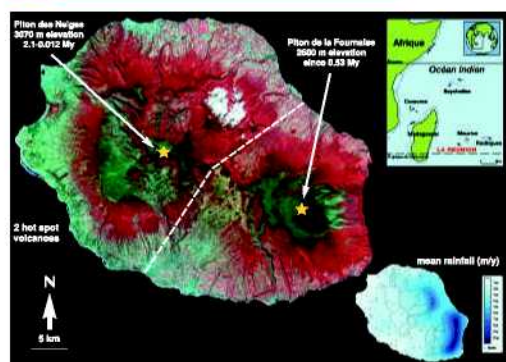
Sources of very high heavy metal content in soils of volcanic island (La Réunion)

Emmanuel DOELSCH^{*,*},
Hervé SAINT MACARY^{*}
and Virginie VAN DE KERCHOVE[†].
*CIRAD-CA, RELIER Group,
BP 20, 97408 Saint-Denis Messagerie
Cedex 9, France
†Chambre d'Agriculture de La Réunion,
MVAD, 24 rue de la Source, BP134, 97463
Saint-Denis Cedex, France

* Corresponding author. Tel : (262) 262 52 80 30
Fax : (262) 262 52 80 30
e-mail address : doelsch@cirad.fr

The rapid population growth in La Réunion is correlated to an increase of the production of various wastes. Agricultural recycling of wastes is an interesting solution since it enables a reduction of the quantities of mineral fertilizers applied and an improvement of chemical and physical properties of soil. Nevertheless, it is fundamental to control and limit the environmental impact of these practices. Since they can result in organic or inorganic contamination of natural resources. Among the pollutants, heavy metals have been critically examined since they can be toxic to humans, animals and plants. The main objectives of this investigation were: (1) to determine soilborne heavy metal concentrations and distributions in La Réunion, and (2) to identify the origin of heavy metals present in La Réunion soils.

Materials and Methods



La Réunion (2,507 km²) is a small french island located (55°30' E, 21°05' S) in the Western part of the Indian Ocean (Figure 1). This island is formed by two volcanoes: the extinct Piton des Neiges volcano and the Piton de la Fournaise volcano.

The climate of La Réunion is both tropical and oceanic with east prevailing winds. The volcanic origin of La Réunion together with the tropical climate and compact orography are key factors that determined the soil formation and distribution patterns on the island [1].

The 20 investigated land units (LU) are shown on the map in Figure 2. When possible, cultivated soils and uncultivated soils, located in the same area, were sampled. 39 sites were selected, with one to three horizons sampled at each site giving a total of 84 soil samples analyzed for Cd, Cr, Cu, Hg, Ni, Pb and Zn.

Figure 1. Satellite picture of La Réunion

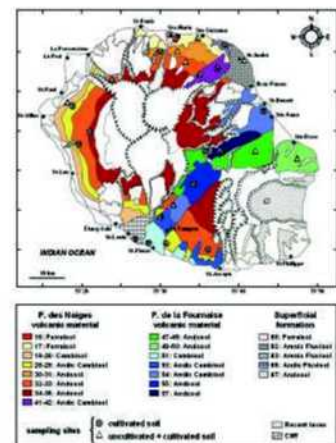


Figure 2. Simplified pedological map of La Réunion (adapted from [6]) with sampling sites.

Results and discussion

Table 1: Characteristics of the total soil population (N=84 soil samples, mg/kg).

| | | Cd | Cr | Cu | Hg | Ni | Zn |
|-------------|---------|------|-------|-----|------|-------|-----|
| La Réunion | minimum | 0,02 | 35 | 6,5 | 0,03 | 15 | 57 |
| | mean | 0,19 | 300 | 58 | 0,19 | 206 | 162 |
| | maximum | 0,76 | 1 108 | 164 | 0,81 | 1 038 | 398 |
| World Soils | mean | 0,53 | 54 | 25 | <0,1 | 22 | 64 |

Heavy metal concentrations in soils of La Réunion are high and present a broad range of values (Table 1). For Cr, Cu, Ni, Hg and Zn, the mean concentrations in soils of La Réunion is much higher than the mean concentrations of world soils [2].

• **Pb** concentration are not displayed in Table 1. Indeed, lead concentrations were below the limit detection for 83% of the soil samples. This is consistent with the low concentration of Pb in ultrabasic rocks such as basalt [3]. When Pb is detected, its concentration sharply decreases from surface to the deep horizon (data not shown). This behavior clearly indicates a **local contamination** of soils.

• Heavy metal concentrations were compared in cultivated and uncultivated soils and significant remarks can be done only for **Cd**. In 9 cases out of 11, Cd concentration is higher in cultivated soil.

These patterns could be explained by **agricultural practices** since phosphate fertilizers are Cd rich [4].

• The concentrations of **Hg** in mafic rocks (0.01-0.09 mg/kg [2]) are very low compared with that of soils of La Réunion (mean concentration: 0.19 mg/kg). Standard emission sources (e.g. waste incineration) can not be evoked since they do not exist, but La Réunion island has a natural emission source: the active volcano. It has been shown that **volcanic emissions** of Hg have a direct effect on local soils [5].

• The studied soils are divided into three groups (Figure 2) according to the parent material: (i) Piton des Neiges volcanic material (LU 16 to 41-42); (ii) Piton de la Fournaise volcanic material (LU: 47-48 to 57) and (iii) superficial formations (LU: 80 to 87). In Figure 3, we have reported Cr concentrations as a function of the parent material. We can clearly observe 3 subpopulations: the soils with the lowest concentrations correspond to the soils developed on the Piton des Neiges volcanic material, the soils with the highest concentrations correspond to soils developed on the Piton de la Fournaise volcanic material and soils developed on superficial formations which have intermediate concentrations. Similar remarks can be done for Cu, Ni and Zn (data not shown). Thus, for **Cr, Cu, Ni and Zn**, high concentrations can be explained by the **origin of parent material**.

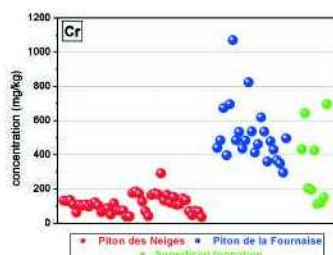


Figure 3. Cr concentrations as a function of the parent material (LU are classified in ascending order from 16 to 87).

To confirm this assumption, we compared the heavy metal concentrations in soils with the concentrations in volcanic rocks from which the soils were formed [6]. This comparison (Figure 4) revealed the close relationship between Cr, Cu, Ni and Zn content in soils and volcanic rocks. This clearly indicates that the very high Cr, Cu, Ni and Zn concentrations of La Réunion soils are mainly determined by the **natural pedo-geochemical background**.

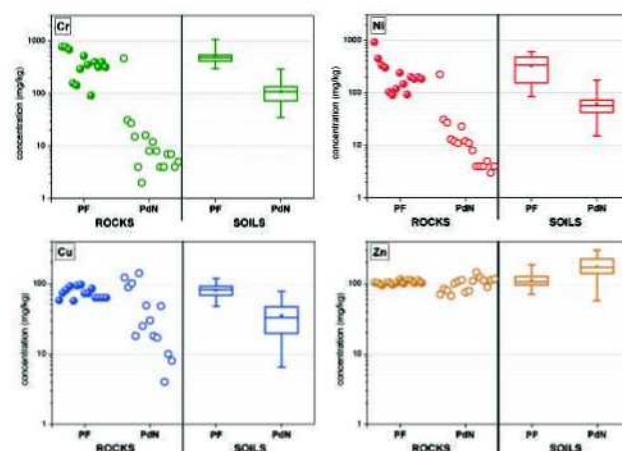


Figure 4. Comparisons of Cr, Cu, Ni and Zn concentrations of soils with concentrations in the volcanic rocks from which the soils were formed. Heavy metals concentrations of rocks are shown on the left part and concentrations of soils are shown on the right part of the graph. PF=Piton de la Fournaise and PdN=Piton des Neiges.

Conclusion

84 soil samples (39 sampling sites) were analyzed to determine the concentration and distribution of heavy metals (Cd, Cr, Cu, Hg, Ni, Pb and Zn) in La Réunion soils. Agricultural practices could explain the high Cd concentrations in soil surface horizons, whereas the high Hg concentrations could be explained by the geogenic origin related to the volcanic activity. For 17% of the studied soils, the high Pb concentrations were certainly due to local contamination by human activities. We demonstrated that the natural pedo-geochemical background could explain the Cr, Cu, Ni and Zn concentrations of La Réunion soils.

In France, a single legislative reference takes soil quality into account for sewage sludge recycling (decree n°97-1133 of 12/8/1997). 85% of the studied soil samples had an Ni concentration higher than the standard values beyond which sewage sludge spreading is not authorized (59% for Cr, 10% for Cu and 3% for Zn). Heavy metal concentrations (Cr, Cu, Ni and Zn) could limit the use of sewage sludge spreading in La Réunion. On the basis of our findings, it would now be essential to undertake further studies to determine the speciation and mobility of these elements in La Réunion soils. This would enable us to determine the bioavailability of heavy metals in soils and to assess the possibility of recycling organic wastes in agriculture without damaging the environment or the health of consumers.

Acknowledgements

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References

1. Rauret, M., Le milieu physique et les sols de l'île de la Réunion. Conséquences pour la mise en valeur agricole. 1991, Montpellier: CIRAD IRAT. 438.
2. Salas-Venegas, A. and H. Pardo, Trace elements in soils and plants. 2nd ed. 2001, Boca Raton, Fla.: CRC Press. 413.
3. Davies, B.F., Lead in heavy metals in soils. B.J. Alloway, Editor. 1995, Blackie Academic & Professional: Glasgow. p. 206-223.
4. Gray, C.W., et al., The effect of long-term phosphatic fertilizer application on the amounts and forms of cadmium in soils under pasture in New Zealand. Nutrient Cycling in Agroecosystems, 1999, 54(3): p. 267-277.
5. Nriagu, J. and C. Brecken, Volcanic emissions of mercury to the atmosphere: global and regional inventories. The Science of the Total Environment, 2003, 304(1-3): p. 3-12.
6. Doelsch, E., V. Van de Kerchove, and H. Saint Macary, Heavy metal content in soils of La Réunion (Indian Ocean), submitted to Geoderma, 2005.



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